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14. ABSTRACT

The Valley Hospital proposes to continue and expand their current work to implement an Emergency Department (ED) Patient and Mobile Equipment Tracking pilot project in an effort to identify key opportunities to drive operational efficiency, improve patient satisfaction, and increase asset utilization. The project will also focus on researching opportunities to leverage the technology in a military setting in collaboration with the Telemedicine and Advanced Technology Research Center (TATRC). The proposed research project intends to demonstrate the effectiveness of using middleware to homogenize data produced by varied real time location system (RTLS) platforms for consumption by a common user interface and application. The project is intended to lead the way to further study of the application throughout the hospital in the inpatient and peri-operative setting.

15. SUBJECT TERMS

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Hypothesis
This research sets out to prove that diverse, disparate, wireless real-time location tracking technologies can co-exist in a single environment and that the positional information they provide can be merged into a single set of data outputs (timestamps capturing milestone movements) that can provide a single pane-of-glass view of the real-time location of materiel assets, clinical process management and patient flow that these data outputs can also be sent to ancillary asset and workflow systems based on their parochial interests. We further believe that, by enabling this homogenization of information supplied by the most appropriate RTLS systems that are installed, we can improve operational efficiency, improve patient satisfaction, increase asset utilization and positively impact patient safety.

Introduction
The Valley Hospital implemented a real time location system (RTLS) in tandem with radiofrequency (RFID) tagging to expand their work on medical error reduction, operational efficiency, patient satisfaction and asset management. The goal for the introduction of this technology was to increase the amount of time that the care giver is able to spend with their patients. The premise being, that increased time between caregiver and patient will reduce the chance for medical error or patient harm.

The RTLS system has been used to locate clinical equipment by tagging each piece of equipment with a RFID tracking tag. The application reduces the time spent looking for clinical equipment needed for the patient. The data collected by the RTLS software and is passed through interfaces to disparate systems for the purpose of preventative maintenance and repair of tagged equipment by the Biomedical and Engineering departments.

In a similar way, on admission, the patient receives a RFID tracking tag to wear. The RTLS tracks the patient as they move through their process of care. This is of particular interest in the ED setting where the patient is often moving quickly from place to place. The benefit of this process provides the ability to locate a patient in real time and to measure the amount of time the patient spent through segments of care (known as key performance indicators- KPI.) KPI's were defined in earlier work through an operational efficiency initiative entitled, ASPIRE, which looked at patient through put across all clinical services. The data collected for each KPI has been captured through a manual process. With the implementation of RTLS/RFID the system was designed to capture the patient's movements in real time provides an electronic source of KPI data. The ability to access real time location at a glance is a satisfier to the patient's family and the attending physician looking for the patient in the busy ED.

The project encompasses building a hospital-wide infrastructure with the RTLS hardware in order to define a zone-based configuration needed to adequately track patients and equipment. The ED was chosen as the development site for RTLS implementation. The patient flow, the clinical work flow, the scope of services and the clinical equipment used in the ED, is representative of patient and clinical work flows in other areas of the hospital and therefore was thought to be a good testing site for RTLS.

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Background
The RTLS was implemented in a phased approach to accommodate the absorption of the technology and integration with existing clinical workflow processes and computerized information systems. The first phase of the project was implemented in the Emergency Department (ED) to study patient flow and mobile equipment tracking in that area to identify key opportunities to drive operational efficiency and improve patient satisfaction.

Technical Objectives:
The specifications for selection and implementation of the RTLS included:

- Relevant room-level or bay-level positional information for tagged movable assets and patients admitted to the ED as well as zone positional information for all other areas of the Hospital Emergency Department.

- Compliance with all RF transmission guidelines to avoid interference with Hospital's wireless communication systems and clinical modalities.

- User-configurable, rules-based workflow and notification components to guide information delivery and notification processes for key events. Identify opportunities to leverage the use of the RTLS Server rules to enhance patient throughput initiatives and other operational efficiencies through the improved utilization of materiel assets, coordinated event alerting based on key relevant positional triggers to improve workflow processes.

- Interface to the Hospital's Emergency Department information system to provide real-time positional data which will be processed by the information system to display the current location for each admitted patient.

- Interface to the Hospital's bio-medical device asset management system. This interface will provide real-time positional data which will be processed by the asset management system to facilitate asset location for any device needing repair.

Military Significance
The ability to create a method for homogenizing location data from disparate RTLS systems will allow multi-vendor sourcing of hardware and accelerate the adoption of multi-site implementations. Current manual asset management processes often cause insufficient availability of assets, labor-intensive physical inventories, shrinkage and inadequate asset maintenance as well as uncertainties in readiness status, which can impact the critical patient care issues. Real-time asset management systems based on RTLS technology can reduce inventory requirements, ensure adequate inventory to meet operational demands, minimize shrinkage of assets, and improve productivity and accountability. The technology platform being introduced will enable these benefits and provide an open framework on which vendors can create solutions.

The military already has disparate RTLS systems actively deployed. This project would allow for the continued selection and implementation of diverse RTLS technologies that

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are designed to meet the environmental and process requirements while enabling cross-departmental information sharing and more effective asset mapping for logisticians.

Public Purpose
This project would provide a framework for product evaluation and selection by organizations wishing to invest in RTLS technology but confused by the diverse solutions and lack of standardization. Our project will afford organizations the opportunity to select the most appropriate RTLS technology solution(s) for their environment while allowing for information-sharing requirements to parochial, legacy information systems. Wi-Fi-based RTLS systems could coexist in the same organizational ecology as RF/IR systems based on the department or unit's needs. The positional information available from each RTLS would be processed by the centralized RTLS Server and integrated through its rules engine to spawn correlated event notification to interested parties and present a holistic view of managed assets.
In addition to the technical application advancement, the ability of the system to generate milestone marks as well as location of patients and assets will be a tremendous assist to gaining healthcare efficiency, increased patient satisfaction and enhanced patient safety.

Healthcare organizations struggle with the ability to track their assets for example, I.V. infusion pumps. The ability to readily locate pumps at the moment they are needed will ensure the patient is receiving their medication therapy in a timely manner, which is an important patient safety issue. The fact that the employee didn't have to spend an excess amount of time to locate the pump is an employee satisfier. The system's ability to track assets will help organizations to purchase the right amount of pumps and create cost savings.

The ability to track patients through their steps in the care process using a real time location system will help healthcare organizations learn what processes can be improved upon to increase efficiency and provide timely, safer care for patients. The milestone marks generated by the RTLS will be far more objective allowing benchmarks to be established so healthcare organizations can use them in their process improvement activities. In so doing, care will be delivered to patients in a way that will minimize risk, minimize bottle-necks in the system and hasten diagnosis and start of treatment to the patient. In addition, creating capacity for staff to spend more time at the patient's bedside.

Collectively, these enhancements will create safe, patient-centered, effective, efficient and timely care. These elements reflect the vision of health care for the American public written in the Institute of Medicine's report, "Crossing the Quality Chasm."

Methods
The testing methodologies were designed to confirm the accuracy of the solution. The asset is displayed on an electronic map that consistently corresponds to a real-life physical location. The process for vetting the solution required repeatable results establishing positive identification that an identified asset or patient on the RTLS Server location matches it's real-life, physical location whether it be zone-based or room-based level of granularity. The testing was performed using a tagged asset and patient. Using

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the positional reference software map contained in the RTLS Server, observation and comparison to the physical "real life" location was made. The testing was deemed successful when a statistically significant number of occurrences in which the tagged asset and patient was confirmed to be displayed within 3 feet of its "real life" location. In zone-based coverage areas, confirmation that a statistically significant number of positive occurrences exist, to locate the asset and patient in the software, match the "real life" location. Further testing confirmed that the location information was consistent and was updated in the heterogeneous information system within 300 milliseconds of a location-change event generated from the RTLS.
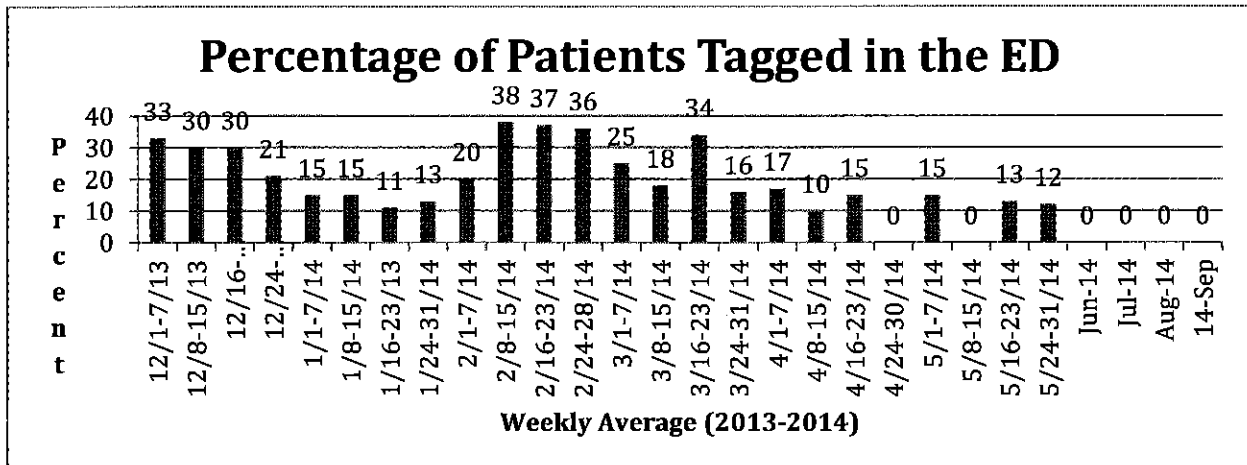
Key Research accomplishments/Reportable Outcomes
Real time patient location: The outbound interface developed between the RTLS host system to the hospital's clinical information system to send the real time location of the tagged patients was accomplished successfully with the result being displayed on the ED tracker board. The tracker board provides an "at-a-glance" view of current patient's logistics and orders status. Successful interface transmission as well on presence on the tracker became the volume load test for the future phase of the project in which all patients from various admission points are tagged and real time location seen on all tracker boards.

Patient Tagging
Getting staff to embrace the change in their workflow and apply the RFID tag and band as well as getting staff and the patient to be aware of the need to remove the tag/band prior to patient discharge continued to inhibit the full development of the project. When the number of RFID tags available for use diminished through loss, it added stress to the cleaning and recycling process. The timing for processing the used tags becomes increasingly time dependent thus allowing less room for slippage and an increased need for accurate accounting of each patient tag. If this doesn't work in synchrony, tags will not be available for patient association which means fewer patients get tagged. The research team spent a great deal of energy working with the ED staff and leadership on a daily basis to increase compliance with the tagging process.
Tag loss mitigation has become the rate limiting step in being able to successfully continue to the patient tagging portion of this project. The graph below shows the percent of patients coming through the Emergency Department (ED) that have been tagged on registration. As tags are lost and inventory diminishes, the ability to clean the tags in designed timeframe is diminished which results in fewer tagged patients. This results in the staff becoming less mindful of the tagging process. The graph below depicts the scenario just described.

Percentage of Patients Tagged in the ED

Bar chart titled "Percentage of Patients Tagged in the ED". Y-axis labeled "Percent" ranging 0 to 40. X-axis labeled "Weekly Average (2013-2014)".

Data values by week:
- 12/1-7/13: 33
- 12/8-15/13: 30
- 12/16-: 30
- 12/24-: 21
- 1/1-7/14: 15
- 1/8-15/14: 15
- 1/16-23/13: 11
- 1/24-31/14: 13
- 2/1-7/14: 20
- 2/8-15/14: 38
- 2/16-23/14: 37
- 2/24-28/14: 36
- 3/1-7/14: 25
- 3/8-15/14: 18
- 3/16-23/14: 34
- 3/24-31/14: 16
- 4/1-7/14: 17
- 4/8-15/14: 10
- 4/16-23/14: 15
- 4/24-30/14: 0
- 5/1-7/14: 15
- 5/8-15/14: 0
- 5/16-23/14: 13
- 5/24-31/14: 12
- Jun-14: 0
- Jul-14: 0
- Aug-14: 0
- 14-Sep: 0

The results of patient tagging on were reported on the I-dashboards created in the RTLS report menu. The essence of the research question posed in this project was to capture defined key movements of the patient through their Emergency department encounter and compare them to the same key movements that are manually captured. The research premise is that RTLS times captured are equal to or shorter than those manually recorded. The results show that average overall arrival to departure of the ED patient to an inpatient unit is 258 minutes which matches to the minute with the manual data capture of 258 minutes.

The average overall time that a treat and release patient spends in the ED through the ASPIRE data collection process is, 164 minutes versus 181 minutes captured via RTLS. The explanation for the difference between the two times is the pediatric patients presented in the ED do not receive an RFID tag. This population of patients has the shortest length of stay in the ED as treat and release patients thus skewing the overall average.

The addition of 2 minutes recorded for Arrival-Enter Triage is accounted in the ASPIRE data collection process as registration time. The RFID tag is placed on the patient at the end of the registration process. Hence the 4 minutes represents the same measurement.

The metric, Admit to ED IP departure is measured with different timestamps in ASPIRE versus RTLS however it was the design intent to capture the same segment of movement. In the ASPIRE timestamp the measure begins at registration and ends when the patient status is changed to inpatient in the hospital information system. In the RTLS system the capture begins on registration and ends when the patient physically departs the ED by passing the signpost at the department exit.

Comparison ASPIRE/RTLS ED Times
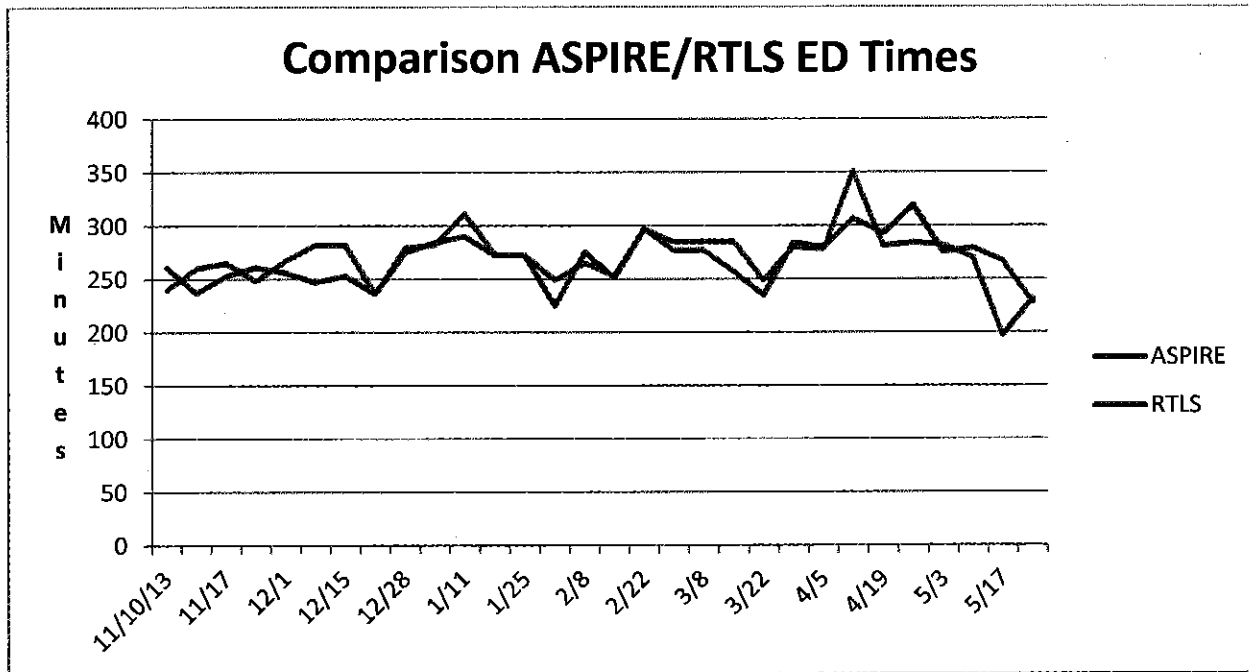
Results of comparing timestamps captured via RTLS vs. manual ASPIRE timestamps indicate RTLS timestamps are on average 10 % shorter.

Comparison of other metrics is showing RTLS times to be shorter than manually entered times for the following timestamps in all but 1 instance:

Metric	Duration(Min) ASPIRE	Duration (Min) RTLS
Arrival- ED Departure	190	181
Arrival - ED Departure In Patients	258	258
Arrival - Enter Triage	6*	4
Enter Triage - Exit Triage	9	9
Arrival-Enter ED Exam Room	20	18
Enter ED Exam Room - ED Departure	190	186
ED Drop Box Departure - Discharge	N/A	15
Arrival - Discharge	196	200
Admit - ED IP Departure	59*	67
Admit - Enter IP Room	99	99
ED IP Departure - Enter IP Room	N/A	32

The RTLS/RFID patient tagging process provided the opportunity to redefine the KPI for the process of patient discharge from the ED to an inpatient room in the hospital. The ASPIRE measure for this segment of care was defined by the time in which the order to admit the patient was received to the time that the transport staff came to the patient from the ED to their inpatient room. With RTLS/RFID this process measure was now able to capture in 2 sub-processes. 1. Admit-ED IP Departure: the time the admission order for

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the patient was received to the time the patient was ready to depart the ED. 2. ED IP Departure-Enter IP room: measured by the time the .transporter took the patient from the ED to the time of arrival to their inpatient room. The data is displayed in the above chart as, Admit-ED IP Departure. In the ASPIRE metric, it was under-estimated by 8 minutes.

Asset Tagging
The Asset RFID tagging and RTLS technology has made the role of Materials Management coordinator at The Valley Hospital much more efficient and has allowed the role of the position to be expanded and add value to the organization. Before equipment was RFID tagged, the Materials management coordinator would have to round on all of the in-patient units searching for clinical equipment. Once the equipment was inventoried, the next step in the process would be to make another round to move the equipment between units to re-establish par levels. This would take a full 8 hour shift every day to accomplish and inhibit the ability to accomplish other duties.
With equipment RFID tagged, the Coordinator can ensure that clinical equipment can be located in seconds via computer screen then the round to patient units is minimized to visiting locations having equipment over par and moving to the identified unit that is under par. Total daily time spent to complete the process averages 1 hour per day or a gain of 7 hours per day. This time savings translates to a salary and benefit savings of approximately $75,000. In this process, equipment is utilized more frequently instead of being static in unoccupied patient rooms or clean utility rooms, monitor if equipment was cleaned properly by environmental services and ensure that yearly maintenance dates are met for all equipment.

RFID tagging has also been used to improve the management of Code carts. Adding an RFID tag has helped the Central supply and distribution department eliminate supplies from reaching their expiration dates. This will reduce product waste and increase workflow by being able to approach time dependent work with predictability.
In a recent mock regulatory survey, it was noted that equipment cluttered corridors which block egress in case of emergency further, excess equipment increase the hazard of trips and falls for patients, visitors and staff. Diminished storage has perpetuated over the years as space once designated for storage of equipment has been redesigned into clinical functioning space or office space. At the same time, advances in technology have facilitated the purchase of even more equipment.

In response to these findings, the materials management coordinator created an inventory of all equipment using the RTLS system. The use of the equipment was assessed by movement history found in the RTLS system. Excess equipment was then sent to an off-site location. The RTLS system was able to be utilized by adding a sign post to read the RFID tag at the location. The RFID tagged inventory is then delivered back to the hospital as needed in a "just-in-time" delivery scheduling process to support the equipment needs at the hospital and timely removal of equipment not needed on site. The equipment can also be monitored for use and preventative maintenance. Upward of 200 pieces of RFID tagged equipment have been moved to the offsite location and are successfully being managed by the process described above. The impact on space gained in the hospital by the movement of equipment to the offsite location is approximately,

7,000 square feet. This has made a significant impact particularly in long narrow corridors where accessibility of every linear foot can make a difference in safety. The offsite location has a 15,000 square foot capacity.

The RFID/RTLS technology can further assist in the successful management of equipment supply and storage logistics. However, before further development can take place, a process needs to be developed to manage asset tag battery life. At the onset of the RTLS project the RFID tag manufacturer projected the battery life of the tags to be 3 years. The investigator's experience is showing an actual life of 1.5 years. With frequent equipment movement as well as numerous access points, the battery is drained much

The Valley Hospital HCAHPS Scores		
Question	2Q 2012-3Q 2013	4Q 2013-3Q 2014
Communication with RN	84	85
Responsiveness of staff	67	70
Communicates about medication	66	68

more quickly.

A low battery equipment tag report has been developed and generates a list of tags that fall below a threshold of signals which indicate the battery has limited life. The information is then parsed to either the Biomedical engineers to be address during clinical equipment preventative maintenance process or the Engineering department managing larger transport equipment, beds, stretchers, wheelchairs, etc.

The ability to locate equipment that has a dead tag which is no longer being tracked by RTLS is being addressed by reviewing equipment movement history but at best, the process poses a great challenge.

The RTLS reports that show equipment movement history will be used to identify opportunities to reduce the quantity of inventory of particular pieces of equipment. One of the main goals is to determine the right amount of equipment needed in the organization.

One of the goals of this research project was to determine if the RFID recording of ASPIRE-KPI data captured by RTLS would have an impact on patient safety and satisfaction. The Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey data reported for the time period of the RTLS integration, 4th quarter 2013 through 3rd quarter 2014 as well as baseline data, 2nd quarter 2012 through 3rd quarter 2013 shows an increase in patient satisfaction in questions that correlate to care giver presence at the patient's bedside. Valley Hospital HCAHPS score of 85 for communication with RN, places the hospital ahead of all hospitals in NJ. The US benchmark score is 79 and the NJ benchmark score is 77.

Conclusion and Lessons learned
The research has demonstrated the ability to create timestamps to capture segments of patient flow in order to measure a patient's movement through particular segments of care while in the Emergency Room using RFID and RTLS. This success is attributed to the ability to accurately recreate the key performance indicators (KPIs) as defined in the

ASPIRE workflow into timestamps using RTLS. The output of this design allowed for an accurate comparison of the data between the manual process and RTLS system.

The hypothesis that RTLS can provide times equal to, or possibly shorter, than the manual data entry process was proven to be a true statement and therefore providing a reliable data source.

Experience with RFID and RTLS in managing assets has proven to be an effective, efficient and job satisfying technologic advancement. As described earlier in this report, the continued development of its application in order to optimize the number of pieces of equipment to have, the process for cleaning, repair and preventative maintenance and all the logistics of equipment movement will be mapped in a future phase of this project.

All the RFID tags require monitoring for low battery. The patient tags require a cleaning and a recycling process which adds time, resources and complexity to the process of patient tagging. Once the battery is dead the RTLS is no longer able to track the tag which results in a cumbersome process for locating the tagged equipment. This diminishes compliance and acceptance of patient tagging, increases cost.

The cost of an active patient tag necessitates recycling the tag which then relies on a process by which the staff and the patient accept responsibility for its removal prior to discharge from the hospital.

In part, the research project intended to demonstrate the effectiveness of using middleware to homogenize data produced by varied real time location system (RTLS) platforms for consumption by a common user interface and application. This was demonstrated by the ability to send location information through an interface to the hospital information system and generate a real time location of a patient on a tracker board for hospital staff and patient/family benefit.

In the midst of this project, the vendor made the business decision to split their RTLS product. They have decided to further develop the asset tagging and management tracking product and to sell the patient tagging and management product. A new vendor purchased the patient and staff tagging product and is interested in enhancing their present patient tagging product to provide a metric for measuring patient through put.

This new opportunity has reinvigorated interest in continuing this research with the knowledge that the technical capability exists. It is recognized anecdotally, that ability to track clinical equipment electronically is having a similar impact on work flow for nurses and non-licensed assistive personnel as it has for the Materials management coordinator. In future research there is interest in having staff wear a RFID tag in order to capture staff movement by creating a timestamp. The staff and equipment timestamps could then be mapped in a table to measure workflow in relation to moving equipment. In a similar fashion, the staff movement timestamps could be mapped in a table to measure the time the clinical staff spends with the patient.

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